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DIAGENESIS IN THE WAHGI VALLEY SEQUENCE, NEW GUINEA

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[Communicated by Dr A. B. Edwards 14 July 1960]

Abstract

The Wahgi Valley sequence consists of Permian and Upper Jurassic to Miocene sediments on a Palaeozoic basement. In the Chim and Wahgi Valleys 24,800 ft of strata are present below the base of the Miocene, and these were once overlain by a probable 10,000 ft of Miocene sediments. The Cretaceous portions of the sequence contain andesitic tuffs and greywackes which have been diagenetically modified as a result of deep burial.

The sediments which have been buried to 13,000-28,000 ft exhibit modifications characteristic of the laumontite facies of diagenesis. Plagioclase is albitized and locally replaced by laumontite, which also replaces radiolaria and organic carbonate and acts as a cement. At depths in excess of 28,000 ft prehnite is found as a cement, and replaces radiolaria and plagioclase. This represents the prehnite-pumpellyite facies of diagenesis. Throughout the sequence rock fragments are modified to chlorite and albite, often without destruction of fabric.

Load pressures of 2-2·5 kilobars appear to be necessary for strong development of the prehnite-pumpellyite facies under normal conditions of epigenetic diagenesis. An accurate estimate of the temperatures obtaining is impossible.

Introduction

The Wahgi Valley sequence was first examined by Noakes (1939), and subsequently the stratigraphy was described in some detail by Rickwood (1955), who recognized the following sequence in the Chim and Wahgi Valleys:

Miocene:	Marls	300 ft + (top faulted)
Eocene-Oligocene:	Chimbu Limestone	2,000 ft
Upper Cretaceous:	Chim Group	12,000 ft
Lower Cretaceous:	Kondaku Tuffs	6,000 ft
Upper Jurassic:	Maril Shales	4,000 ft
Permian:	Kuta Formation	800 ft
	Palaeozoic Basement (metamorphics)	

80 miles NW. of the Chim Valley, but only 8 miles across the regional strike, the Miocene is represented by the Gai Group, 10,600 ft of shales and greywackes.

The Kondaku Tuffs are described by Rickwood (1955) as consisting of 'well bedded volcanic breccia, tuff, conglomerate, greywacke, siltstone and shale'. The Chim Group is described as 'shales with occasional cone-in-cone structure, greywackes and tuffaceous mudstones'.

Edwards and Glaessner (1953) have described in some detail a suite of sediments collected from the Chim Group, Kondaku Tuffs and Maril Shales. Through the kindness of Dr A. B. Edwards, to whom the author is deeply indebted, the author was able to examine thin sections cut from this suite of sediments. Hand specimens were unfortunately not available. These thin sections formed the basis of Edwards's and Glaessner's paper.

In view of the thoroughness of Edwards's and Glaessner's descriptions repetition of petrographic descriptions here would be superfluous. The arenites are mainly lithic labile greywackes (Crook 1960a) of andesitic derivation, with some quartz admixture. There are also some andesitic tuffs.

Although Edwards and Glaessner recorded many of the diagenetic features of these sediments, they were not primarily interested in the distribution of the various features with depth. It is with this aspect of the diagenesis that the present paper primarily deals.

Depth of Burial

It is apparent from the stratigraphic sequence that the basement in the Wahgi Valley region has been buried to a depth in excess of 24,000 ft. Assuming that the Gai Group once extended SW. into the Wahgi-Chim area, without appreciable loss of thickness, one concludes that the basement has been at a depth of the order of 34,000 ft. It is conceivable that this figure may be too low, by a few thousand feet, as the top of the Gai Group is missing due to erosion. However, it is equally conceivable that there has been some thinning of the Gai Group towards the Wahgi-Chim area, for Rickwood (1955, p. 77) considers that the Miocene marls on the Chim R. were deposited in shallower water than their equivalents in the Gai Group. The figure of 34,000 ft would thus seem a good first approximation. This is referred to as the 'present stratigraphic depth of burial' of the basement

Diagenesis

The suite of samples covers a range of present stratigraphic depths from 13,500 ft to 33,000 ft. Unfortunately the lithologies represented between 17,000 ft and 22,500 ft and below 30,000 ft do not yield useful information on diagenesis, and it is therefore necessary to extrapolate certain data across the central part of the sequence.

Data on depth distribution of the various diagenetic modifications are summarized in Fig. 1. Throughout the sequence the plagioclase is albitized—very slightly clouded and sparsely flecked with sericite—and volcanic rock fragments are modified, usually without destruction of fabric, to similar albite and chlorite. The composition of the albite was not determinable from the material available, but it seems unlikely that it is different from that in the Parry Group of N.S.W. (Crook 1960b)—An_{2-4}, to which it is morphologically closely similar.

In those parts of the sequence above a present stratigraphic depth of 28,000 ft, the plagioclase is, in addition, partly replaced by a zeolite which is usually laumontite, but other species may also be present. Laumontite, at times accompanied by another undetermined zeolite, is found replacing shell fragments and radiolaria, and acting as a cement throughout the same region of the sequence. These instances are similar to those in the Parry Group of N.S.W. (Crook 1960b) (replacement of plagioclase, and cement) and the Southland sequence, Otago (Coombs 1954) (replacement of plagioclase, shell material, and cement). Laumontite replacement of shell material has also been observed by the author in fossils from Watts, Babinboon, N.S.W., at the top of the Parry Group.

This portion of the sequence is also characterized by small granules of authigenic sphene, which occur between the detrital grains, associated with other diagenetic products. These granules are again matched by occurrences in Southland and the Parry Group, N.S.W.

In specimens from present stratigraphic depths in excess of 28,000 ft prehnite appears as a cement and as a replacement of plagioclase. Occurrences are closely similar to those in the Parry Group, N.S.W. Prehnite also occurs replacing radio-

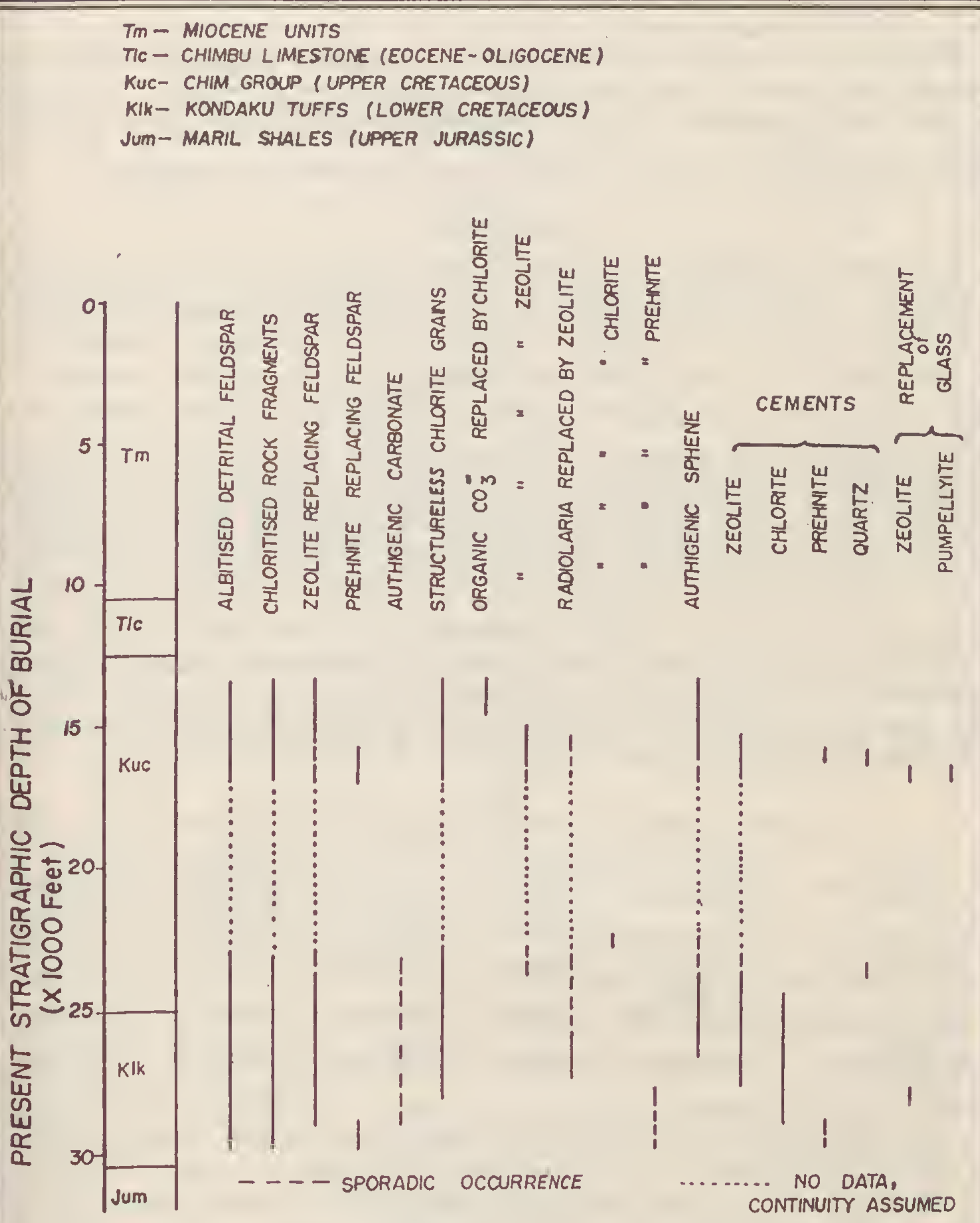

FIG. 1

DISTRIBUTION OF DIAGENETIC EFFECTS IN THE WAHGI VALLEY SEQUENCE, NEW GUINEA.

laria, a phenomenon noted in certain radiolarian argillites from the Tamworth Group, N.S.W. (Crook 1960b).

Prehnite also appears locally higher in the sequence, at 16,000-17,000 ft, replacing plagioclase and acting as a cement. One specimen, 9022, shows it strongly developed, and associated with quartz as veins. In another specimen within this depth-range, 9026, there is a fibrous pleochroic green mineral, already noted by Edwards and Glaessner (1953, p. 106), which is apparently pumpellyite.

Discussion

The overall similarity between the Wahgi Valley sequence and parts of the Southland, N.Z. sequence (Coombs 1954) and the Tamworth Trough sequence, N.S.W. (Crook 1960b) is obvious. The already described diagenetic depth sequences have been ascribed by Coombs et al. (1959), Coombs (1960) and Packham and Crook (1960) to the effects of elevated temperatures and pressures attendant on deep burial. There seems little doubt that the Wahgi Valley depth-sequence is of similar origin.

The application of the facies principle to these rocks (Coombs et al. 1959, Packham and Crook 1960) leads to the conclusion that the Wahgi Valley sediments from present stratigraphic depths between 13,000 and 28,000 ft can, for the most part, be assigned to the zeolite facies (laumontite diagenetic facies). Those from depths in excess of 28,000 ft can be assigned to the prehnite-pumpellyite diagenetic facies. The Wahgi Valley sequence, then, is the third described example of a diagenetic depth sequence in sediments which still retain their original clastic fabric.

The stratigraphic depths at which the prehnite-pumpellyite facies is first encountered and at which it becomes dominant in these three sequences (Table 1), give approximate values for the load pressures obtaining, assuming a density averaging 3 g/cm^3 for the overlying rocks (see Fyfe et al. 1958, p. 34).

TABLE 1

Depth of appearance of prehnite in diagenetic depth sequences

Locality	Reference	Depth of first appearance	Inferred pressure	Depth of maximum development	Inferred pressure
1. Southland, N.Z.	Coombs 1954	23,000 ft	2100 bars	—	—
2. Tamworth Trough, N.S.W.	Crook 1960	18,000 ft	1650 bars	28,000 ft	2500 bars
3. Wahgi Valley, N.G.	herein	16,000 ft	1450 bars	28,000 ft	2500 bars

It is interesting that the Tamworth Trough and Wahgi Valley sequences should yield such similar data, for the sequences are petrographically very similar. As the load pressure at any depth is constant, and the water pressure may be assumed to equal the load pressure at the depths in question, it seems likely that similar geothermal gradients have obtained. This is in good accord with Fyfe and Verhoogen's point (Fyfe et al. 1958, p. 195) that the temperature in a sequence undergoing modification is dependent, among other things, on the rock types present in the sequence. The differences between the Tamworth and Wahgi sequences and the Southland sequence are possibly due to differences in geothermal gradient which may be a reflection of the different rock types present.

The data in Table 1 suggest that load pressures of 2-2·5 kilobars are necessary for strong development of prehnite-pumpellyite facies modifications under normal conditions of epigenetic diagenesis. Occurrences at shallower depths could be ascribed to local elevation in temperature, or to decrease in the activity of water (i.e. decrease in the partial pressure of water) in the manner suggested by Ellis and Fyfe (Coombs et al. 1959, pp. 81-83).

No estimate can be made of the temperatures at which the prehnite developed. Tuttle and Bowen's data on geothermal gradient measurements (1958, p. 188) cover a wide range of values, and the most that can be said is that the minimum temperature of formation of prehnite experimentally (300°C.) observed by Ellis and Fyfe (Coombs et al. 1959) is a not impossible temperature for the natural formation of prehnite in the sequences under discussion.

Acknowledgements

This study was commenced while the author was on the staff of the Geology Department, University of Melbourne, and was completed at the University of Alberta during the tenure of a Postdoctorate Fellowship of the National Research Council of Canada. The author wishes to thank Professors E. S. Hills and R. E. Folinsbee for making facilities for study available, and to Drs A. B. Edwards, J. F. Lerbekmo and F. A. Campbell for helpful criticism of the manuscript.

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